

The principal point of entry of these winds into the United States is along the northern border between the eastern slope of the Rocky Mountains and Lake Superior. It is the general impression that they flow southerly in shallow surface currents whose vertical extension is at no time great enough to permit the cold air to flow westward thru the low passes of Wyoming and Colorado into the Great Basin. In confirmation of this view I quote an incident related by Prof. F. H. Loud, in *Colorado College Studies*, volume XI. The incident relates to observations that were made on a cold wind that suddenly sprang up on October 24, 1904, in front of an approaching anticyclone. There were three parties concerned in the observations, one on top of Pikes Peak (14,108 feet), the second at a camp, 3,000 feet above Colorado Springs, and the third at Colorado Springs (5,981 feet). At the last-named place a great cloud canopy was seen early in the morning approaching from the north; it was attended by a sharp increase in the wind, the latter springing at once to a velocity of 26 miles per hour, and the temperature began to fall. At the camp, 3,000 feet higher, the wind did not begin to blow until four hours later, at which time the cold-wave front at the lower level was probably 50 to 100 miles in advance. On the top of Pikes Peak, only a gentle west wind was experienced, with moderate temperatures. It should be said that the mountain climbers did not set out to make meteorological observations, hence the absence of definite readings at the several altitudes. These observations show clearly, however, the flow of a cold surface current under a mass of warmer air, which it evidently lifts up without disturbing its equilibrium and causing it to flow away on both sides. The diffusion of the cold upward is very slow and in this case it did not reach the summit of Pikes Peak. The moisture in the air was sufficient to form dense clouds, but only a trace of rain fell at the lower station.

The rapid southward flow of extremely cold air is one of the most striking characteristics of the winter climate of the Missouri Valley and the Plains States. The sharp and decided temperature falls which attend these phenomena can hardly be explained on the ground of radiation alone, altho radiation from the air itself and the earth's surface becomes effective in lowering the temperature as soon as the wind abates. On the front of the anticyclones which issue from the northwest the wind velocity over the Plains States generally exceeds 30 miles per hour, occasionally 40 miles per hour. These velocities are sufficiently great to constantly renew the air at any given point and thus maintain the low temperature it had in more northern latitudes, regardless of the influence of insolation during the daylight hours and the warmth of lower latitudes. The chief cause of the low temperatures on the front of anticyclones seems to be, therefore, cooling by transported air from high latitudes plus radiation. The latter is effective in proportion to the rate of movement of the anticyclones, being greater in proportion as the motion of the latter is slower.

### IS THERE A TYPE OF STORM PATH?

By EUGENE VAN CLEEF.

(Read before the Association of American Geographers, December 30, 1907.)

In my first studies of the daily weather maps, the movements of centers of storm areas across the country were noted. These were the centers of low pressure areas, or cyclonic storms, and the centers of high pressure areas, or anticyclonic storms.<sup>1</sup> Further research revealed an apparent succession of such centers passing along the same, or very nearly the same, paths. With this observation the possibility

of forecasting seemed to be attainable, and I undertook a determination of the paths of type storms. I wish to extend my thanks to Dr. J. Paul Goode, of the Department of Geography of the University of Chicago, for his many valuable criticisms and suggestions while this work was in progress.

Before discussing my methods or results I wish to define three terms:—"Type", "type path", and "type storm."

A "type" is that which is representative.

A "type path" is a well-defined course which is representative.

A "type storm" is a storm (either a high or a low) that is representative of all storms exhibiting nearly the same characteristics.

In as much as storms of the same type should follow the same type paths, and inasmuch as the paths of storms were the available data, the latter were classified with the results described in the following paragraphs.

The MONTHLY WEATHER REVIEW of the United States Weather Bureau gives in detail each month the paths of the centers of high and low pressures crossing the country during the month. A period of ten years, from 1896 to 1905, inclusive, was selected, this length of time being ample as a fair basis for conclusions. This period includes 1,160 paths of "lows" and 928 paths of "highs," or a total of 2,088 paths, averaging 208.8 per year. The paths were plotted upon separate card maps of the United States, size 4 by 6 inches, in order to facilitate classification.

The cards were first classified according to the mean paths of storms, as shown in chart 2', Bulletin 20, by Professor Bigelow. This classification could not stand; many storms that really deserved to be alone had to be placed with types. The classification was extremely elastic, but had to be more rigid. Casting aside all suppositions and thoughts of what the type paths ought to be, the cards were arranged by similarity, i. e., all the paths which resembled one another were placed together.

The first assortment was rather rough. Crude as it was, about 30 sets of lows and 24 sets of highs resulted. Not satisfied with this result the cards were reassorted; some were removed from one set and placed with others, or new sets were made. This method was not entirely satisfactory. It seemed now that it would be essential to define the type storm.

In accordance with the definitions given above by me, I reclassified two or three times. But still there was another limitation which seemed necessary, a limitation relative to the width of the "type belt." Four hundred miles was considered as the average width of "storm areas," or possibly a little less than average.

Then recalling the definition of a "type storm," namely "a storm which is representative of all storms exhibiting nearly the same characteristics," and adding the limitation of the path to a type belt 400 miles in width, another classification was attempted. Finally a satisfactory classification was reached including a certain number of sets of similar storm paths, a certain number of unclassified, and a certain number which were incomplete and therefore had to be entirely excluded.

The next step consisted in resolving the various sets into paths representative of each set. This was carried out not by mere superposition, but by a process of elimination. Two paths were charted upon a base map in one color, the resultant was drawn in another color (Charts IX-X); two more were charted in still another color, and their resultant drawn with the same color as in the first. Then the resultant of the two resultants were drawn in a fourth color—thus for four storms. I proceeded by fours in this manner, then resolved

<sup>1</sup> The word "storm" is applied here to any disturbance of the atmosphere, whether due to a high barometric pressure or to a low one, many of which are not storms in the ordinary acceptance of that term.—C. A.

<sup>2</sup> This chart 2 of the Weather Bureau Bulletin No. 20 was reproduced in a leaflet entitled "Explanation of the Weather Map," and is not here given as it is easily accessible.

the resultants of the fours<sup>3</sup> until the semifinals (Chart XI) were reached, when these were resolved for the final, and the final plotted alone. This now was my "type" storm of the set in question. Thus carrying out the same process with each set, always treating the paths of highs and lows separately, I obtained a set of lows and highs and plotted them as represented herewith in Chart XII, paths of lows, and Chart XIII, highs.

The lows included 1,160 cases, of which 983 are classified, 57 miscellaneous, and 120 incomplete which can not be considered. The highs included 928 cases, of which 741 are classified; 98 are miscellaneous, of which 57 can not be classified owing to their peculiarity of running northward parallel to the Pacific coast before entering the country and then dispersing along various courses; 89 are incomplete and accordingly can not be considered.

Before discussing these results as types attention is called to a few striking features shown on these charts.

*Cyclones, lows, Charts XII and XIV.*—Notice first the apparent unity of first appearance in the northwest altho certainly not the origin, with the trend of path into the interior of the country from northwest to southeast, then the dispersion in the Mississippi Valley and the reunion toward the northeast. Again, notice the crossing of the Cordilleras by many of these lows, but the absolute avoidance of the Appalachian region.

There is an apparent, tho not too well defined, tendency for the lows to avoid bodies of water, one belt extending across Sault Sainte Marie, another belt across Michigan, and still other belts passing on either side of Lake Erie, but not crossing it.

Note the parallelism with the coast line of lows moving northeast along the Atlantic coast.

*Anticyclones, highs, Charts XIII and XV.*—There is an apparent origin in the northwest, as in the case of the lows; then a trend from northwest to southeast, a dispersion in the Mississippi Valley, continued, however, to the Atlantic without reunion.

Here, in contrast with the lows, there is an absence of storm paths in the Cordilleras and a freedom in crossing the Appalachian region.

Two "type-paths" seem to find their origin somewhere off the coast of California and travel northward, entering the country around the northern edge of our maps.

From the statistics at hand, as a matter of interest and possibly significance, I plotted two curves, one (Chart XVI), showing the "Annual variation in storm frequency; average of ten years," indicating a maximum of storms in November, December, and January and a minimum in June, July, and August; the other (Chart XVII) showing the "Secular variation in storm frequency during eleven years," exhibiting an apparent 5-year rythm. Possibly after some fifty years more, statistics alone considered, we may be able to decide definitely as to this rythm.

Charts XII and XIII should represent "types of paths." Keeping in mind the definition of type path and the limitation as to the extent of a type path belt, I sought to learn whether these charts really represent types. No doubt the large number of type paths here shown is open to criticism; it may be said that some of these paths might be consolidated quite readily into one, or that 400 miles is entirely too limited. However, on the contrary, even greater limitations might be set.

Chart XVIII shows two paths of low centers which at first one might believe could be very easily consolidated. They enter the country together in the Puget Sound region and leave it together on the eastern coast, moving along the same course

toward the northeast. So far as these two positions are concerned they might be legitimately consolidated. But by following the paths across the continent we find a prominent divergence at Calgary, continuing thru Williston southeastward, reaching a maximum at Charles City, Iowa. It is quite evident that a low on path A will not have the same influence on South Dakota in passing eastward, as a low on path B. Again, a low of given characteristics in longitude 90° W. will not affect Chicago, for example, on path A as it will if on path B. From longitude 115° W. to 80° W. a low having certain well-defined characteristics, if following course B will be affected by the influence of the western mountain ranges for a longer time than along course A. I believe that the Great Lakes<sup>4</sup> are also an important factor in influencing the movements of storms in the vicinity, so that a storm on path A would not be affected by the Lakes as one on path B. If this be so there is good reason for differentiating finely as long as slight changes in path mean considerable changes in character.

Of course it is much simpler to have but 10 types. It is far easier to determine whether a storm belongs to one of 10 types than to one of 48. Then besides 48 types, there is a total of 364 storms which can not be classified. If the classification had been still more rigid, the number of types would have been increased to half as many again. The presence of the large number of so-called "types" and the possibility of securing more, leads to a slight suspicion as to the soundness of the "type" hypothesis.

Possibly under ideal conditions, such as uniform flat topography, no lakes, no seas, no large rivers, one might be able to determine quite easily and precisely all the type storm paths. But mountains, lakes, seas, oceans, forests, and plains do exist, and are possible factors in the courses pursued by storm areas and in the determination of the effects of a storm on the regions concerned. Local influences<sup>5</sup> are oftentimes enormous factors affecting the characters of highs and lows. As to exactly what their effects may be we know very little. With the numerous possibilities involved in altering the paths and the characters of storms, the difficulties of classifying according to types increase rapidly, and the idea of "types" as a basis for forecasting completely breaks down. I began by assuming that types should enable us to forecast with ease the future position of any storm. But the variations possibly due to the influence of local conditions makes the forecast almost a lottery. The "type" is really no longer a type, except under well-defined conditions. As the same well-defined conditions rarely repeat themselves this means that the type storms rarely repeat themselves; accordingly there is either a type storm for every condition (which means that each storm must be a type in itself) or there is no type.

Waldo<sup>6</sup> recognizes that a large number of types of maps must exist:

It is possible to class weather maps in a general way according to certain types, but the number of these types is very great. Probably over 100 typical forms would be necessary for such classification; some one of them might occur only at intervals of several years, while others would occur several times in a year.

The very fact that there is a great number of apparent type paths is detrimental to the practical value of the theory of types in forecasting. If only a few storms go to make a type, wherein is there any advantage in having "types?" A "type" stands for something striking—something distinctly noticeable. It is almost impossible to recognize a storm as belonging to a given type if there are only ten or twenty such storms in the course of ten years. If there be types which make their appearance only during some years and not during others, this would still further increase the difficulty of attempting to de-

<sup>3</sup> See Monthly Weather Review, November, 1907, Vol. xxxv, p. 516-520.

<sup>4</sup> The winds of the Lake region." Prof. A. J. Henry.

<sup>5</sup> Lehrbuch der Meteorologie, Dr. J. Hann, 1906, 2d Ed. p. 319-322.

<sup>6</sup> Waldo, Elementary Meteorology, p. 284.

<sup>3</sup> Where less than four paths were classified in the preliminaries proportionate weight was assigned them when the final classification by four's was made.

clare whether a storm belongs to the intermittent or the regular types. Confusion would be the only result.

A few statements by Pernter<sup>7</sup> are worthy of notice. He says:

It was by this means demonstrated that there is an extraordinarily great variety of forms of atmospheric pressure distribution; that these, however, can be classified into a certain number of types by having regard to the form as well as to the weather conditions given in these forms. \* \* \*

The knowledge of the weather conditions for every place and for every type of pressure distribution offers the only entirely satisfactory empirical basis for weather predictions; moreover, it is by this knowledge alone that we can hope at some time to discover the fundamental laws of the changes in the weather.

Pernter would be correct if ideal conditions prevailed. If one must depend upon types, he will have to wait a long time to discover the "fundamental laws of the changes in the weather." Had Pernter used the expression "variation of pressure distribution," instead of "type of pressure distribution," then his statement would be true; but presence of a "type" assumes the existence of types, which is the problem to be solved first.

In the United States Weather Bureau leaflet, above referred to as "Explanation of the Weather Map," the following statement is made, accompanying the chart of "mean tracks and average daily movement of storms in the United States:"

The first impression of a student of the weather maps, as they present their seemingly endless forms and combinations of the temperature and pressure lines, is often one of confusion.

The storms of the United States follow, however, year after year, a series of tracks, not capricious, but related to each other by very well defined laws.

Then, after a detailed account of various possibilities of paths which a storm might assume in crossing the continent, a statement is wisely added, which, however, defeats the hypothesis of type paths:

The chief difficulty in the art of forecasting is to decide which of these paths will be pursued and the probable rate at which the movement will take place.

This is the problem exactly, "which paths will be pursued and the probable rate of movement." If we had a type, we should certainly know the path which a storm would pursue and the exact conditions attending it at every point; but we know by experience, an experience consisting primarily in failures of forecasts, that a storm very often does not follow an expected path nor does it bring about hoped-for conditions, but quite often does just the reverse of what is forecast; sometimes it remains stationary for several days; at times it becomes intensified and moves on with great velocity; again it weakens and moves more slowly; often it apparently splits in two or dissipates entirely.

The eccentricities of storms are well illustrated by many sets of weather maps. Those for the period of November 28 to December 3, 1907, show very nicely the irregular movements of storm areas—the stationary high in the West, a series of swiftly moving lows about the high and of course moving from west to east, a local development of a low in the Mississippi Valley and the movement of the high in the West after having been stationary for six days.

This series of maps and forecasts shows that even the expert forecaster may often be completely at sea, and that it must be misleading to say that—

By preserving the weather charts each day and noting the movements of the highs and the lows any intelligent person can make an accurate forecast for himself, always remembering that the lows as they drift toward him from the west bring warm weather and sometimes rain or snow, and that as they pass his place of observation the highs following in the tracks of the lows will bring cooler and probably fair weather.<sup>8</sup>

If the distinguished author means that a truly accurate forecast can be made so easily as this, the statement is quite optimistic. It does not require a great deal of study to con-

vince one that under present conditions it is no easy task to forecast with accuracy. The writer here quoted has probably forgotten that it is his long experience which makes forecasting seem easy.

Considering then:

1. What a type storm is;
2. The number of apparent types;
3. The lack of ideal conditions;
4. The presence of local influences;
5. The results of experience in forecasting;

I feel thoroly convinced that there is no type storm; that the type storm as a basis for forecasting must be discarded if we hope ever to arrive at an era of accurate forecasting; that a more thoro study of local influences must be made.

#### THE PRESENT AND FUTURE STATE OF MARITIME METEOROLOGY.

By H. HERGESSELL, Director of the Meteorological Service of Alsace-Lorraine.  
[Translated from the German version in Gaea, August, 1906, p. 480-486.]

By the term "maritime meteorology" I understand the science that has to do with the processes occurring in that part of the atmosphere lying over the sea. The distinction between the oceanic and continental portions of the atmosphere is not only logical but also requisite, for the reason that most meteorological processes are conditioned not merely by direct solar radiation, but also by the thermal interrelations of the atmosphere with the liquid or solid surface of the earth.

The earth's surface exercises so great an influence on the diurnal variation of temperature, the distribution of water vapor, and the occurrence of convectional currents that we can understand these phenomena only by taking into account the sources of heat which this surface offers. As to its thermal action, the surface of the sea is essentially different from that of the land. The land surface receives a certain quantity of heat during the day, and loses it again at night by radiation, so that a rapid alternation takes place and the heat does not penetrate deep into the ground. The solar rays are less readily absorbed by the water surface than by the land, but they penetrate deeper. For this reason, and also on account of the difference in specific heats, the temperature of the water changes less than that of the land, altho the quantity of heat absorbed is decidedly greater. Moreover, the surface temperature of the sea water falls but little, relatively, at night, since the water, as it cools, is immediately replaced by warmer water from the lower strata. This essential difference in behavior between sea and land fully justifies the distinction between maritime and continental meteorology. While our knowledge of the latter has made great progress, our knowledge of the former has made but little; a fact easily explained by the difference in the conditions of observation. Over the land surfaces whereon we dwell, and particularly in civilized countries, meteorological studies are easily carried on; they are, in fact, to a certain extent forced upon us. We have known for a long time, and with considerable accuracy, the laws which govern meteorological processes over dry land; tho, to be sure, our modern methods of investigation have been arrived at but gradually. We began with observations at the earth's surface, then erected mountain observatories, and finally penetrated to the upper, free atmosphere, with the help of kites and balloons.

In the domain of maritime meteorology work has been much less active. Its history is bound up with that of the great oceanographic expeditions, among which the *Challenger* expedition, the scientific voyages of the Prince of Monaco, and the cruises of the *Gazelle* and the *Valdivia* take first rank. The meteorological investigations which these expeditions carried on were, moreover, limited to the lower strata of the atmosphere; only very recently, thanks to the initiative of the Prince of Monaco, has the study of the upper air been taken in hand. We should not, therefore, be surprised that our

<sup>7</sup> Monthly Weather Review, December, 1903, vol. xxxi, p. 579, 580.

<sup>8</sup> Nat. Geog. Mag., March, 1907.